An Inaugural Essay on the Vacuity of the Arteries after Death

Passed March 13th 1827
W. L. He.

by

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of
Philadelphia

Submitted to the examination
of the
Trustees and Faculty
of the
University of Pennsylvania

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The Vacuity of the Arteries after death, is well known to prosecutors of morbid anatomy, and to Med=
=ical Men generally; but no satisfactory explanation has yet been advanced of this phaenomenon

In speaking of his experiments, Dr. Harlan says. "I now thought that the phaenomenon in ques=
"=tion was explained, by supposing the blood to circulate "in the veins, whilst no more was propelled into the "Aorta and arterial canals, the latter was of course "emptied. — But I was soon convinced, that though "the principal objection was obviated, the experiment "did not explain in what manner that portion of "blood, forced into the aorta by the last contraction "of the left ventricle, found its way independent "of any "vis a tergo" through the whole extent of the "arterial canals to the mouths of the veins. This "constitutes the problem to be solved; and it was of "this in particular, Dr. Wistar asserted, he had

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"never heard any satisfactory explanation offered;
"although he had availed himself of frequent oppor=
"=tunities, of conversing with men of science upon
"this subject; Some of whom argued the pressure
"and action of surrounding muscles, as the cause;
"others the pressure of the external air; but he
"remarked "the elasticity of the coats of the arteries
"would resist any such pressures, and prevent the
"obliteration of their Calibers." Eclectic Repertory vol. 9 th.

However interesting to the Physiologist and
to the Medical Practitioner, this subject of itself
might be, its importance is much increased when we
consider, how closely it is connected with the subject
of venous circulation.

As various powers have been assigned as causes
for the blood flowing from the extreme arteries, back
to the heart, it will be proper to mention them,
and separately to take them into consideration.

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1st. By Richerand, Venous Circulation is ascribed chiefly to the contraction of the veins themselves.

2nd. by Harvey, by Majendie, and by Spalanzani, it is attributed to the action of the heart alone.

3rd. by Barry and Carson it is asserted, that Venous Circulation is owing to a vacuum formed in the Chest; and by the latter of the two, that the vacuity of the arteries after death depends on the same cause

4th. While Bordeu, Bichat, and some others place the power almost exclusively in the Capillaries

Other Powers have also been assigned in aid of those above mentioned viz. the action of Muscles, the elasticity of the arteries &c.

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varicose vein; – by puncturing a vein between two li=
=gatures; and by the superficial veins assuming different
sizes, according as the surface is exposed to a warm or
a cold atmosphere.

But this contractility is very little more than
sufficient to accomodate them to the quantity of their
contents, and is inferior in force to the power driving
the blood on from behind, hence the distension of a vein
on the application of a ligature, or on any other cause
obstructing the course of the blood; and hence
also the engorgement of the veins in death.

That the blood does not circulate in the
veins by their contractility, may be seen by the
following experiment.

Select that part of a superficial vein on the
arm or hand, where there is a space of one inch
or more between two valves, without receiving any
branch laterally: place one finger on the lower
valve, the vein then between the finger and the

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upper valve remains full as before, which it would not do, if the vein was the cause of the motion of the blood. Then with a second finger force what blood remains between the first finger and the upper valve, above that valve; the vein being empty below, and the blood still remaining above the upper valve distinctly points out its situation. Lastly raise the fingers, and instantly the emptied portion of vein fills, showing that the motion of the blood depends on a "vis a tergo"

Which is also shown by the following experiment related by Majendie in his work on Physiology page 304 he passed a ligature around the thigh of a dog, without including the crural artery or vein, and then applied a ligature on the vein near the Groin, when on making a slight opening into the vein, the blood escaped in a considerable jet, he then pressed the artery between his fingers, to prevent the arterial blood from reaching the member, the blood did

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not stop on this account, but continued some instants, gradually decreased, and at length stopped, though the whole length of the vein remained full: the artery contracted by degrees and became completely empty, the blood of the vein then stopped: at this period by ceasing to compress the artery, the blood injected by the heart, entered, and soon as it had reached the last divisions, began to flow again at the opening of the vein, the jet increasing gradually till the same as before. He then compressed the artery anew till it was emptied, and then let the arterial blood into it slowly, the flowing of the blood from the orifice of the vein took place, but there was no jet till the artery was entirely free

Those who attribute venous circulation to the heart, differ somewhat among themselves: Some combine with the propulsive action of the heart, the elasticity of the arteries: Others say the heart acts

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However necessary the contraction of the left ventricle is to send the blood to the extreme arteries, yet that it is not necessary for venous circulation is proved by that going on, after the impulse of the heart has been cut off by a ligature or by pressure applied on an artery; the circulation thus going on till the arteries become exhausted of their contents, as in the above experiment of Majendie. — Though Majendie inferred that venous circulation was owing to the propulsive action of the heart, and the elasticity of the arteries (for contractility he does not admit). Yet I think a different construction might be put upon it, which will be mentioned hereafter

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matter the following experiment was made by myself with the assistance of a fellow Student: We confined a full grown Cat on its back, with the legs extended horizontally; an incision was made into the Abdomen, and a ligature drawn tightly around the inferior Cava and aorta above the bifurcation: the inferior Cava was then punctured with a Lancet just below the ligature, the blood flowed immediately and continued flow=ing, as we judged, between 10 and 15 minutes. In ¾ of an hour from the application of the ligature, the animal being dead, the Femoral and Subcla==vian arteries were examined and found alike empty, the corresponding veins were engorged with blood. —

Inference. As the blood flowed from the Vena Cava, and the arteries became empty after the impulse from the heart had been cut off, we must infer, there is a power independent

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of the heart, capable of propelling the blood into and through the veins; nor could this be the contractility of the veins, for the Femoral veins remained full although there was an outlet for the blood, by the opening in the inferior Cava.

That venous Circulation depends on the heart, is also contradicted by the following experiment extracted from Spalanzani's work on the Cir=
=culation page 359. "I placed (he says) a ligature "on the middle of the descending aorta of a Frog: "the portion betwixt it and the heart increased in "capacity, and became a deeper red, whilst that "portion beneath the ligature was pale and col=
"lapsed, and although it retained only a small "quantity of blood, its diameter did not appear in "the least diminished"

That the heart attracts the blood by dilatation, and thus causes its motion in the veins, is contra=
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by the experiment of Majendie; and by that made by myself, in which a ligature was passed around the vein: It is also contradicted by the universal venous engorgement that takes place after death

The opinion of Carson, to which much attention has been paid, that the circulation of the blood in the veins, and that venous engorgement is owing to the tendency in the Lungs to form a vacuum by their resiliency; which he supposes has the effect of draining the blood from the different parts of the body, until this vacuum is filled.— On which account it is the arteries are found empty after death, there not being blood enough to fill both arteries and veins.

This opinion has already been confuted in the Fifth Vol. of the Philad.a Medical Journal, by Tennel, who with the assistance of Dr. Lawrence repeated Carson's Experiments, with an entirely different result.

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Carson killed some Rabbits by opening the thorax, thus causing the Lungs to collapse, and the vacuum if any existed to be destroyed. In these Rabbits he found the Muscles red bleeding on being cut, the transparent membranes much injected, and the veins collapsed. While in Rabbits killed by puncturing the spinal Marrow the Muscles were white and dry, the membranes not injected, and the veins engorged.

But in Fennel's repetition of these experiments, not the least difference could be perceived in the whole circulation between animals killed in the two different ways, except the lungs of those killed by collapse, were of a lighter colour and contained no blood; he found the venous system of sufficient capacity to contain the blood independent of the vacuum formed in the Lungs.

But Carson has not shown that a vacuum really existed after death. And by the following experiment

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extracted from Williams's paper on the obstruction of the blood in the Lungs, in the 13th. No. of the Journal of Foreign Medical Science; We see, that the engorgement of the veins and the right side of the heart may go on after the Chest has been laid open, and all vacuum of course destroyed.

"An Animal was killed by securing the Trachea "at the acme of inspiration, and the sternum and "cartilaginous ends of the ribs were removed, in presence of Dr. Traill. The blood in the pulmonary veins "was observed to change its colour to a darker hue as "the current lessened. Immediately after the last systole, "the left ventricle felt contracted: then an irregular "action of the muscular fibres of the right ventricle "commenced, which lasted for some time. — By "mistake, one of the branches of the pulmonary artery "traversing the right lungs was divided instead of "a branch of one of the pulmonary veins, which "poured out blood copiously. As soon as the mistake

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"discovered, the bleeding was staunched by the fingers
"of an assistant. After opening the pericardium, the
"right auricle and ventricle became greatly distended.
" One of the pulmonary veins traversing the left
"lung was now punctured, and a small quantity
"only of blood oozed out. Then the blood which had
" accumulated in the left auricle and ventricle,
"was discharged, by making a free opening into
"the former of the two cavities. After it was discharged
"no more blood flowed or oozed out of that opening,
"or from the puncture that was in the vein.
"Yet at the same time blood continued to be returned
"vigorously from the system at large, to the right
"cavities of the heart. After a while the pulmonary
"artery was punctured, which was followed by a copious
" discharge of its contents. The windpipe was lastly
"divided and the lungs instantly collapsed, with
"considerable rapidity, until then no visible diminution
"in their bulk had taken place. To satisfy

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"ourselves that the vessel that bled so freely was a branch
"of the pulmonary artery, a probe was passed into it
"from the right ventricle. After the action of the
"heart had ceased, we were much astonished
"at the vitability of the diaphragm, producing repea=
"=tedly the most perfect contraction of that muscle
"all the others were at rest"

Did this vacuum, (alluded to by Carson) exist, why should the blood leave the the arteries, forming a vacuum there, in order to destroy one existing in the chest. But I do not consider there is a perfect vacuum in the arteries after death, for it is probable they are filled with the halitus that escapes from the blood when drawn into a vessel; or with some other gas: but as blood is also contained in the vessels about the Lungs, the gas would be as likely to supply the deficiency there as in the arteries.

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should be equally empty after death occasioned by Lightning, as when occasioned by puncturing the spinal marrow, for the resiliency or elasticity of the Lungs and arteries, to which he attributes this phae=
=nomenon, is, as he acknowledges a property of texture, and of course must continue long as that texture remains perfect. — But the arteries are not empty when death has been occasioned by lightning. The reason for which will be offered hereafter.

While I deny that the emptiness of the arteries after death is caused by a vacuum existing in the chest, I do not deny that venous circulation during Life is promoted by the vacuum, caused by the expansion of the chest in inspiration; this has been proved by Barry. — But still I cannot consider with him that this vacuum is the chief cause; It only removes the blood from the great veins in the neighbourhood of the heart, which become distended during expiration.

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from the vena cava, after a ligature had been placed on it near the heart, or puncturing it below the ligature, (as in venaesection). On Barry's hypothesis it ought not; But the blood does flow, as has been heretofore shown.

I have come now to the opinion of Bordeu, Bichat, and some others, namely. That venous circulation is owing mainly to the action of the capillary vessels: an action, the existence of which has been much questioned: and from the mi=nuteness of the vessels, difficult to be discovered by the eye: therefore, we are forced in some measure to reason from analogy.

That Capillary vessels are endowed with a power of propelling fluids, seems evident from the economy of Plants and Trees, they have no heart. Yet a fluid is taken up by the minute capillaries of the roots, is conveyed a considerable height to

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undergo the necessary change in the leaves, and from thence is conveyed, and deposited in other parts, for the growth, for the reparation of injuries. &c. — But confining myself to the animal economy, and passing over the abdominal circulation, where the blood distributed through the arteries to the different viscera, passes then through minute vessels to a large trunk, is conveyed through it, and minutely distributed in the substance of the Liver, then once more is collected into large vessels before it reaches the vena cava, in its way to the heart. —

But passing over the abdominal Circulation, we have an instance in the Intestines, of a tube propelling its own contents, even when they are nearly solid, by contractions obvious to the sight. — Certain inferior animals also, have no heart, their blood is circulated by the action of the vessels themselves. And it is to the same kind of action, we must

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attribute the flow of fluids, from the different secretory glands, as the testes, the salivary glands &c. But in the lymphatics and lacteals the analogy is more striking; by these a fluid is taken up, conveyed by their own contractions, a greater or less distance, notwithstanding the obstruction from the convolutions in the lymphatic glands, and eventually is emptied into the left sub-clavian vein. — And this action of the absorbents continues after the contractions of the heart has ceased, as may be seen by examining the mesentery of an animal killed a short time after having been fed.

Substances also have been injected into animals, after being bled apparently to death, and were taken up by the absorbents, and discovered in other parts by Chemical tests. Barry's experiments do not prove, (as he thinks) that absorption depends upon atmospheric pressure, they only prove that the forces by which Lymph is propelled, is inferior in degree to

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the pressure of the atmosphere, and that when put in opposition to the absorbents, the motion of the fluid in these vessels is checked, or its course reversed.

That Capillary vessels possess a power of contraction, is supported by the following extracts.

"Instances occur, when from passions of the mind, "from a sudden great revulsion by blood letting, or con= "= vulsion, the blood has retroceded from the smaller "into the larger arteries. And in like manner from "an obstruction being formed in the venous branches "above the valves, the blood has been known to "return into the extreme branches." Haller, page 31

Speaking of the blood in the Capillaries Bichat says "In the ordinary state, it moves generally in "an uniform manner, from the arteries towards the "veins: but at every instant, it may find causes "of irregular oscillations in its numerous anasto= "= moses: hence as we have seen the necessity of "these anastomoses. These irregular oscillations

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"in the motion of the blood in the capillary system,
"can be seen with a microscope. Haller, Spalanzani
"and others, saw them a hundred times. They
"saw the Globules advance, recede, move in many
"different directions, in animals with red and cold
"blood, when they irritated the mesentery, or any other
"transparent part." General Anatomy, Vol. 2nd page 37

If then the blood can advance or recede from a given point, by irritating that point, there must be a power located there, by which the blood can be moved.

The powers assisting venous circulation, namely. The Elasticity of the arteries, and Muscular action no doubt have some effect; but that elasticity is not the cause of their vacuity is evident, for though empty, that elasticity prevents their parietes from coming in contact, hence they retain their Caliber after death. Nor is the action of the muscles in=

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indispensably requisite, for the blood circulates in a paralytic limb, and in one perfectly quiet. The proof commonly advanced in support of the effect of muscular contraction, namely, the increased flow of blood by it in venaesection, is not so strong as we at first may think, for by the swelling of the bellies of the muscles, the deep seated veins are compressed, and more blood must seek a passage through the superficial veins.

But it is the chief cause I am enquiring after, a cause without which venous circulation can not go on.

In speaking of capillaries, I do not say whether there be a distinct set of vessels interposed between the arteries and veins; nor whether contraction exists only in the capillaries, or the minute ramifications of arteries performing functions attributed to capillaries; or whether contraction also exists in arteries of somewhat larger size: but according to John Hunter it

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does not exist in the largest, or in the middle sized arteries to any extent. With this explanation I will still use the term Capillaries.

If then the Capillaries possess the power of propelling the blood into the veins: and if this power, similar to that of the absorbents, continues some time after the action of the heart has ceased, it will be sufficient to explain the cause of the vacuity of the arteries after death, provided, there be any other power, by which the blood remaining in the arteries after the last contraction of the left ventricle, can be presented to the mouths of the Capillaries, for them to act upon it.

This can not be the heart, for there is no medium through which it can act, or it has ceased. It can not be the elasticity of the arteries, for this keeps their parietes asunder, preserving their caliber: nor can it be their contractility, for this is denied to arteries of any size, or is inferior to the elastic power.

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But there is another principle which operates on the blood in common with all other matter, viz. Gravity, but which so far as I know has never been applied to explain this phenomenon.

That Gravity influences, by promoting or retarding, the motion of the blood, even in the living body is evident; hence an inflamed extremity is directed to be kept elevated, and hence also in wounds of the palmar arch, where it is difficult to take up the bleeding vessel, the effect in stopping the hemorrhage by keeping the arm raised to a position almost perpendicular. That gravity has an effect on the blood also after death is evident, from that part upon which a dead body has been lying, becoming much injected, while the most elevated part is not.

This effect of Gravity is also supported by the following Experiments. "After having killed "several Salamanders by electricity in order that

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"the blood might not coagulate. I suspended them
"by the head. The blood in the vena cava and aorta
"was instantly precipitated to the inferior extremities,
"but recovered its original situation upon placing the
"animal in a horizontal position. This fluid
"flowed rapidly towards the head, upon reversing the
"salamander, and redescended into the vessels of
"the tail when I changed the position of this
"extremity. The middle sized vessels exhibited
"the same phaenomenon, experiencing only more
"slowly, the effects of gravity, but the circulation in
"the small branches seemed to be little influenced by
"this law." Spalanzani on the Circulation page 85.

"Such was the position of the two umbilical
"arteries of three Eggs, two days after incubation, that
"the power of Gravity could not be contrary to one
"without being favourable to the other. Whilst the
"blood scarcely moved in the first of these vessels,
"it had in the second a rapid and uniform

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"The blood of all animals is endowed with the "principle of Gravity, it is heavier than Lymph or "Water, and whatever be the position of the organs in a "dead body, it accumulates by its own weight in "the most dependant parts. the same phenomena "were observed by Haller in moribund Frogs.

Spalanzani page 384

It may be asked, Why the most dependent parts of a dead body remain injected, If the circulation of the blood after apparent death, is owing to the action of the capillaries. This may be explained by the supposition, that the organic life and action of the capillaries has become so far exhausted, before the blood has ceased flowing to their mouths, that they are unable to propel the last portions.

or we may suppose that the proportion transmitted by the most dependent capillaries is too great for the capacity of the corresponding veins: consequently

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the last portions of blood must accumulate at the commencement of those veins. And further, the injection or dark colour of the most dependent after death, is owing probably more or less to the extravasation of blood, or its percolation into the various tissues of the part.

From what has been said, Gravity, after the action of the left ventricle has ceased, appears sufficient to cause the blood to flow to the most dependent part: And hence, from the aorta, situated nearly in the centre of the body, through either the anterior, the lateral, or the posterior branches, given off from that trunk or from other trunks, to be presented to the mouths of the most inferior Capillary vessels: whose vitality remaining sometimes after apparent death, they are enabled by their own action, to propel on the blood into the venous system, causing the engorgement of the veins, and the vacuity of

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the arteries, that is met with after death.

By the power of Gravity, combined with the action of the capillaries, are we able to explain the phaenomena that took place in Majendie's experiment before related, and in that made by myself. When the impulse of the heart was cut off, in the one case by pressure, in the other by a ligature on the artery, yet the circulation went on in the veins till the arteries were entirely empty

And those phaenomena that take place in death from lightning, do not contradict the above opinions. For here vitality is destroyed in every part of the system at the same instant: the vital action of the Capillaries ceases simultaneously with that of the heart; hence the blood that was contained in the arteries at the moment of death, must remain there; as is found to be the case, excepting what percolates into various Tissues.

What has been said above embraces

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one view of the subject. — It might be considered necessary next to enquire, why the blood does not continue moving — passing through the Lungs into the pulmonary veins, thence into the left auricle and ventricle, and from thence, again filling up the emptied arteries: and thus keeping up an imperfect circulation, till organic life and action in the capillary vessels was expended.

But this part of the subject has, (in the 13th no. of the Journal of Foreign Medical Science in a paper by Williams) been so satisfactorily explained by reasoning and by experiments, one of which has already been related, and as this is in some measure distinct from the other part of the subject, I shall only mention the conclusion, at which he has arrived, namely.

1st. "The Blood is obstructed in its passage "through the Lungs, on suspension of respiration;

"while its circu-
"lation continues
2nd "The
"Lungs on sus-
"of a mechani-
3rd. "The
"on suspension
"=tion of pure
4th. "The blood
"auricle and
"last systole,
"the pulmonary
5th. "The ob-
"suspension of
"causes of the
"arterial blood
6th. "The in-
"the action of
"=nal stimulus,
"the Lungs.

"while its circulation through other parts of the
"body continues

2nd "The obstruction of the blood in the
"Lungs on suspension of respiration, is not the effect
"of a mechanical cause

3rd. "The obstruction of the blood in the lungs
"on suspension of respiration, arises from a depriva=
"=tion of pure atmospheric air.

4th. "The blood found "post mortem", in the left
"auricle and ventricle, is the remnant after the
"last systole, and the subsequent draining of
"the pulmonary veins.

5th. "The obstruction of the blood in the lungs on
"suspension of respiration, is one of the principal
"causes of the vacuity of the system, circulating
"arterial blood, post mortem,

6th. "The immediate cause of the cessation of
"the action of the heart, is a privation of its nat=
"=ural stimulus, arising from the obstruction of the blood in
"the Lungs.

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From his Experiments, Dr. Harlan came to con=
=clusions nearly similar to the above, Phil. e. Repos. vol 9

Here in the last division of this subject, we see the Capillaries of the Lungs refusing to convey the blood from the pulmonary arteries to the pul=
=monary veins, because it had not received by breathing its accustomed alteration, which is necessary to afford the natural stimulus.

While in the first division, the Capillaries of the General system circulate the blood, till the arteries are completely empty, because the blood is in a proper state for affording the natural stimulus.

It will be perceived that nearly all the ex=
=periments related, have been extracted from the writings of other persons. On this account I consider them worthy of more reliance, as they were performed by persons of much greater expe=

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experience in Vivisections than myself, and particularly, as they were not performed with the intention of supporting views herein contained.

To conclude; I shall sum up briefly the opinions I have endeavoured here to maintain

During Life the blood is distributed throughout the arterial system, and presented to the capillary vessels, chiefly by the contraction of the left ventricle: yet is assisted by the elasticity and contractility of the arteries.

Its passage back to the heart, again to go the round of the pulmonary circulation, is mainly effected by the action of the capillaries, though more or less assisted by certain collateral powers, as muscular action, the vacuum formed in the chest by inspiration &c.

But after apparent death, Gravity effects partially, what the heart did during Life, it causes the blood contained in the arteries, after the last

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contraction of the left ventricle, to flow to the most dependent capillaries, to be by them propelled into the venous system.

Thus on the one hand causing the vacuity of the arteries after death; while on the other, they are prevented from being again filled, by the capillaries of the Lungs refusing to cir= =culate blood not changed by Respiration.

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